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HOW TO IMPROVE THE MISSISSIPPI.

THE building of the jetties has transformed New Orleans into a great sea-port. Seven lines of steamers are now employed in her foreign trade. For the year ending June 30, 1883, she was next to New York in value of exports, and ranked third in total foreign commerce; the amount of the latter being $104,704,076. Toward this gate-way of the outer world the Mississippi, with its two thousand miles of main river and ten thousand miles of navigable tributaries, is the natural internal highway. The five feet low water channel over its bars, which, like the canals of a generation ago, sufficed to meet the wants of commerce in years past, is wholly inadequate for present needs, much more for those of the near future. Recognizing these facts, the United States Government has undertaken to deepen and improve the channel of the Mississippi River. For the accomplishment of that end a plan has been adopted, and is now in course of execution. The salient points of that plan may be stated as follows:

To utilize the scouring power of the river for the purpose of cutting away the bars that obstruct navigation; to apply the energy of the river to this work by narrowing the channel over the bars, and thus concentrating its current upon them, obstructing bars being uniformly coincident with excessive width in the present river-bed; to prevent the re-formation of bars by protecting the caving banks above them, from which most of their constituent material is taken; to preserve the energy of the river, unimpaired by outlets or subdivisions of its volume. In a former number of the REVIEW (March, 1882,) were presented some considerations in support of the theory of concentration as opposed to that of diffusion by outlets as a means of improving the channel of the river. These need not be repeated here.

Assuming it to be sufficiently established for the present purpose that it is necessary for the preservation, and much more for an increase, of the river's present low water depth that at all ordinary stages it shall flow in one undivided channel of as uniform width as is practicable, there remains this further and important question, viz.: Is it also in accordance with sound principles of engineering, and will it be in like manner conducive to the improvement of the river, to confine its flood volume within the same channel by artificial additions to its natural banks?

In the study of this, as of all other questions relating to the Mississippi, the river itself is the best teacher. It is, and must always remain, a self-made river. If we can discover the means by which its channel has been made as good as it is, we shall have the surest indication of the means by which it may be made better. It is an obvious proposition that these means are all comprised in scour at the bottom and bank building at the sides. It is also obvious that some extent of bank building must precede any considerable excavation by scour. A thin, unconfined sheet of water has little or no scouring power. Bank building takes place by the deposit of sediment in time of overflow, each flood adding its contribution to the preëxisting bank. It is impossible, however, for water to carry a deposit of sediment quite to the elevation of its own surface. So that a flood of given height cannot build banks high enough to confine a succeeding flood of equal or greater height; but it may carry them high enough to confine succeeding floods of less height. As matter of fact, while the Mississippi River is constantly fluctuating in its stage, comparatively few of the rises which occur in a year, and rarely more than one, go over the natural bank. For the most part, the stream flows, rises, and falls between banks built for it by past floods. These, we will assume, the river has carried to the full height of its unaided arm's length. It is proposed now to make an artificial addition to them in the form of levees. This will do for the greater floods exactly what the greater floods have already done for the lesser,—confine them within a defined channel. Such an addition to the natural bank is plainly a mere continuation of the very process of channel construction by which the present river bed has been made. It is but the finishing of the river's own unfinished work. And if it be a fact that the present magnificent channel, scarcely second to any in the world for navigation, has been created solely by the energy of the water flowing in it, will not an increase of that energy by increase of volume and depth necessarily increase the river's capacity for work, and so result in a deeper and better channel?

There is no doubt that the ability of the Mississippi River to maintain its normal bank height has been greatly diminished by artificial causes. Before the advent of civilized man in its upper valley, every forest, swamp, and grass-covered prairie helped to hold back the rainfall. The effect of clearing, draining, and cultivation has been to send the surplus water of that vast region into the lower river in sudden, short-lived, enormous floods. Furthermore, in a state of nature, the banks of the lower river were everywhere covered with a dense mass of vegetation, which formed a perfect filter for separating the sediment from the overflowing water, and also furnished great protection against caving. Now they are occupied in large part by cleared fields, over which the flood water passes with comparatively little loss of sediment, and which wash into the river easily and rapidly. So that it may be said with truth that the artificial addition of a few feet to the present natural bank is scarcely more than the river itself would accomplish by natural agencies but for the interference of man. There is evidence that the Mississippi had once a narrower channel and higher banks than at present. As a rule, the ancient crescent-shaped lakes in the valley, which, it is certain, were formerly part of the river bed, have banks higher than those of the present river, with intervening width considerably less.

There is another consideration of different, but not less important, character. The fluid which fills the channel of the Mississippi is not, as we are apt to assume, water merely, but a mixture of water and soil,—a fact which cannot be left out of sight for a moment in studying the phenomena of the river. From this flowing mixture, the soil tends constantly to separate. Every diminution of its velocity results in a deposit of solid matter at the bottom. Unrestrained overflow tends to produce diminished and irregular velocity in the main channel, and so to fill it up with sediment.

The grand alluvial basin of the lower Mississippi lies in four natural subdivisions, known respectively as the St. Francis, the Yazoo, the Tensas, and the Atchafalaya basins or fronts. The general surface elevation of each of these basins is lower than that of the immediate banks of the river. The water which escapes across the upper portion of the St. Francis front during an overflowing flood, fills up that basin and flows downward through it until it meets the high lands which touch the river at Helena, where it is forced back into the river. In like manner, the water which escapes across the Yazoo front is forced into the river again by the bluffs at Vicksburg. There result, in consequence, first, a division of the river's volume at the head of each basin, by which its velocity and energy are diminished; and second, an enormous accumulation of water at the foot of each basin, by which its flood level is raised to an abnormal height.

The great floods of 1882 and 1883 presented in this respect a remarkable contrast. That of '82 had free access into the Yazoo basin through numerous gaps in the levees. Prior to the flood of '83, these were repaired so far as to exclude the latter flood almost entirely. During the flood of '82, the maximum stage at Cairo was 51.87 ft. above low water; at Memphis, 35.15; at Vicksburg, 48.75. During the flood of '83, the maximum at Cairo was 51.90; at Memphis, 35.11; at Vicksburg, 43.80. Thus, while the two floods reached almost exactly the same height at Cairo and Memphis, the second fell off 4.95 feet at Vicksburg. The difference is very significant. A reduction of five feet in Mississippi flood level means a great deal. At the maximum stage of '82, the river was thirty miles wide at Vicksburg; at that of '83, it was almost within its banks. The former flood exhibits the action of a slowly moving lake; the latter that of a running river. One flowed steadily toward the sea; the other loitered about over eight thousand square miles of land. After passing Vicksburg, the flood of '83 remained substantially within banks to the Red River. The season following was one of unusually low water. In the upper parts of the river, where the overflow had been greatest, many bars showed only six feet of depth, and some only five. But from Vicksburg down there was abundant and unusual depth throughout the season, no bars showing less than ten feet. The scouring force of this one partially confined flood seems to have produced a marked improvement through one hundred and sixty-eight miles of channel.

The unrestrained overflow of flood-water is also accompanied by constantly recurring local variations of velocity and direction in the main channel. Some parts of the bank are lower than others; some cleared smooth, others covered with timber; some furnish open pathways to capacious reservoirs or bayous, others do not. So that the quantity of water escaping from one part of the river may be very great; from another part, a few miles below, very little. These irregular discharges produce corresponding fluctuations in the velocity and direction of the current, and consequent retardation of flow and deposits of sediment.

An overflow through a series of crevasses located not far distant from each other is substantially like an overflow across the natural bank. The chief difference is that in the former case the sections of discharge are more sharply defined than in the latter, where there is likely to be a thin sheet running over a considerable portion of the entire front, with large discharges at bayous or depressions in the surface. During the flood of '82, a group of four crevasses occurred on the Yazoo front, within a space of eighty miles, the upper one being at Malone's Landing, sixty miles below Memphis, and the others at Riverton, Bolivar, and Mound Place, respectively. The river along this front had been carefully surveyed during the months of January and February of that year, and its depth and cross section at all those points, very shortly prior to the outflow, were accurately known. In October following,—the flood having occurred in the meantime,—a re-survey was made of the river opposite and several miles below each of these crevasses, for the purpose of ascertaining what change, if any, had been produced by them. The results showed a marked filling up of the bed in every case. At Malone's Landing, a small crevasse, the fill amounted to four per cent. of the entire channel space; at Riverton, to fourteen; at Bolivar, eleven; at Mound Place, twenty-four; being an average of thirteen per cent. These overflows, being circumscribed in extent and large in amount, produced correspondingly great shoalings of the water-way within like short spaces. If the same amount of overflow had been distributed over a longer bank front, it is probable that the resulting impairment of the channel would not have been so great at any one place, or so easy to ascertain and measure; but that the tendency and consequence of it would have been the same in kind, seems a very obvious inference.

During the years 1881 and 1882, systematic observations were conducted by the Government at several stations on the Mississippi, to determine its depth, cross section or vertical water area, mean velocity, and discharge, besides some other matters not material here. In these observations may be found some striking illustrations of the tendency of an alluvial stream to obstruct its own path during overflow. At Clayton, Iowa, where general overflow begins at the fourteen feet stage, observations taken during the flood of October, 1881, showed that at that stage the velocity of the current, which up to that time had increased as the river rose, suddenly ceased to increase, and remained substantially unchanged until the rise reached its maximum of eighteen feet, seventeen days later. That is to say, the river rose four feet above its banks without any increase of velocity in its current.

Like observations taken at Grafton, Ill., during the flood of April and May of the same year, showed that as the river rose above its ordinary stage, the velocity of its current and the amount of water discharged increased in the usual accelerating ratio until the stage of general overflow was reached. At that point the velocity and discharge ceased to increase, and, during the last two feet of rise, both actually diminished. To be exact, on April 25th, the stage was 32.17 ft., cross section 67,545 sq. ft., mean velocity 4,594 ft. per sec., discharge 310,309 cu. ft. per sec.; while on May 6th the stage was 34.16, cross section 73,695, velocity 3,859, and discharge 284,405. That is, the river ran with nine inches per second less velocity, and discharged nearly twenty-six thousand cubic feet per second less water at its highest stage than when two feet lower.

At Hay's Landing, Miss., the gauge reading March 20, 1882, was 38.58, cross section 172,105, mean velocity 5.44, discharge 936,900. Ten days afterward, when the river had passed from general overflow to bank-full stage, the gauge reading was 34.14, cross section 167,396, mean velocity 6.26, discharge 1,049,000. That is, a fall of four and a half feet from the maximum, which brought the river within its banks, increased its velocity eight-tenths of a foot, and its discharge a hundred and twelve thousand cubic feet, per second.

In April, 1881, an unusual flood occurred in the Missouri. It originated above Sioux City, and was not augmented by any floods from its tributaries, below. For a distance of five hundred miles it covered the valley from bluff to bluff. There was nothing to retard its progress, except such obstruction as it created itself. Nevertheless, its velocity so slackened as it rose above its banks, and its rise so increased as its velocity slackened, that it reached a height at St. Charles three feet above its relative height at Sioux City; whereas, the normal course of a flood is to diminish in height above the low-water plane as it flows downward. It was observed, also, that the amount of water discharged was less than that which the river was accustomed to discharge at a height seven feet below that of the flood, and within the banks.

It is to be remembered, of course, that in the production of such phenomena as these many forces may coöperate, and they should not be hastily ascribed to a single cause. But it is obvious that in each of these cases there was a choke of some kind in the river. There was no visible obstruction in any of them to create it. It was coincident with general overflow, and did not appear at any other stage. The inference from these circumstances alone, that it was in some way caused by the overflow, is by no means illogical. But there are better grounds for that conclusion than mere coincidence.

A stream of water loaded to its full carrying capacity with sediment, is exceedingly sensitive to change. The particles of sediment swim by means of their friction. Two particles that can barely swim separately will sink if brought into contact, because the contact reduces their aggregate frictional surface. In falling, they will carry down myriads of other particles that can barely swim. So that the least halt in the great procession of particles precipitates part of its constituent membership to the bottom. There they create an obstruction which prolongs the halt; the prolonged halt increases the obstruction, and so on, each condition reacting upon the other. The result is decreased velocity and increased rise in the stream. Just how slight a cause may start this train of causes, it is impossible to tell.

The Mississippi River at Cairo knows nothing of the Gulf of Mexico. It does not flow from love of motion, but in search of rest. Its condition of rest is levelness of surface. Confined in a narrow, descending channel, it can find no rest until it dies in the ocean. But when it overtops its banks there is comparative rest nearer at hand. It becomes a river flowing through a lake. Its buried channel no longer compels it to seek its level in one direction only. It may seek it in any direction, and over thousands of square miles of surface. Moreover, the multiplied curves of the buried channel often lead in directions inconsistent with the general slope of the valley. And so, when the valley is turned into a lake, the slope of the lake surface will sometimes harmonize with, and sometimes contradict, the slope which the river had when within its banks. Amid these complicated conditions, the water pursues its unvarying purpose to seek its level on all sides, and so flows in whatever direction, and with whatever speed, tend most to that end. These considerations alone will go far to account for the piling up of a flood by wide-spread overflow. Thicken the water with sediment, and such a result ceases to be surprising.

Levees have not been constructed heretofore for the purpose of channel improvement. But they have been in use from time immemorial, and in many parts of the world, for protection against overflow, and have in many instances produced an unintended deepening of the channel.

Red River, from Shreveport to its mouth, flows by a crooked channel through an alluvial basin like that of the Mississippi, and is a stream of like behavior with the main river. A few years before the war its levees were made complete and continuous on both sides for a distance of two hundred miles above Alexandria. Their effect in deepening the channel was so marked and immediate that in a few years such floods as had formerly overspread the valley for miles, found room for discharge within the banks, and rarely reached the levees at all. Elsewhere, the shallow channel remained and the river overflowed as before.

The Lafourche is a bayou heading in the Mississippi at Donaldsonville, seventy-seven miles above New Orleans, and flowing thence through the Atchafalaya basin to the Gulf. Its upper portion, for a distance of some sixty-five miles, has been leveed for sixty years. In its lower portion, overflow is unrestrained. Its upper portion has maintained its depth unimpaired. In its lower portion the deposit of sediment has so raised its bed and obstructed its discharge that it has become necessary to build the levees, at and near their lower termini, higher and higher in order to resist the floods, until they now extend twelve feet above their original height; while those above, where the stream has been kept within its channel, remain as they were fifty years ago.

Abroad, the Po, the Rhine, the Seine, and the Thames may be cited as examples of rivers whose channels have been incidentally deepened by means of levees erected for protection against overflow. The bed of the Po in the neighborhood of Ponte Lagoscuro, where accurate data have been preserved, has been lowered one foot within the past century. The levees on the lower Thames were erected about 1767. By 1802 the channel depth between them had increased six feet.

The improvement to be expected from the maintenance of levees will be the result of an increase in the river's effective force as a whole. It will therefore be general in its character and gradual in development, and will not obviate the necessity of works placed in the channel to preserve its banks and cut down its bars. It is in connection with these, and as part of a complete and logical system of improvement, that they have their proper place.

An important distinction exists between the ordinary floods of an alluvial stream—that is, those which occur with a degree of regularity from year to year—and its extraordinary floods, which occur only at irregular intervals. The former are part of the river's normal life; the latter are not. In the work of channel formation, the ordinary flood is the determining force. It is that by which and to which the river shapes its bed as nearly as it can. Therefore, if we can control and utilize the whole force of the ordinary flood in the work of channel improvement, we shall secure the benefit of all the normal energy of the river. The exceptional and abnormal floods may be disregarded. It follows that levees intended for the sole purpose of improving the channel may be of much less height than those intended for protection against overflow. For the latter purpose, they should be able to restrain the greatest floods.

If any artificial additions to the banks of the Mississippi River are necessary to the improvement of its channel for purposes of navigation, it is the duty of the United States to provide them. That much is matter of national concern and national obligation. Protection against overflow is matter of domestic and individual concern, and therefore such levees as are necessary for that purpose should be provided by the communities interested. An ideal levee system would comprise two lines of embankment,—one of comparatively light character, following the river bank as closely as possible, and intended to restrain ordinary floods only; the other a master dike, standing farther back, high and strong enough to withstand all floods, and following the general course of the river in long curves. But such a scheme is too vast for present consideration, to say nothing of the practical difficulty of its execution. And as long as one line of levee must stand at once for river improvement and land protection, the obvious suggestion of nature and justice is that the expense of it shall be divided between the States and the United States, according to its uses. To locate approximately the line dividing those uses is not beyond the possibilities of engineering. To devise measures by which a corresponding apportionment of burdens shall be made, and unity and effectiveness of control secured, ought not to be beyond the resources of patriotic statesmanship.

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